The status of the black bream *Acanthopagrus butcheri* (Pisces: Sparidae) population in Lake Clifton, south-western Australia

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Abstract

Lake Clifton hosts the largest living, non-marine thrombolite (microbialite) reef in the southern hemisphere. The thrombolite reef was recently listed as a critically endangered ecological community. The main threat to the ecology of the lake is increasing salinity, but other threats have also been identified, including the impact of the introduced fish *Acanthopagrus butcheri* (Munro, 1949). Samples opportunistically collected after a fish kill in 2007 indicated that *A. butcheri* in this lake experienced very low somatic growth and recruitment failure between 1995 and 2007, probably in response to hypersalinity. The evidence suggests that the *A. butcheri* population in Lake Clifton is effectively extinct. The proposed conservation strategy for Lake Clifton addresses a range of identified threats, including the eradication of *A. butcheri*. However, management action in response to this particular threat may no longer be required. The abundance of *A. butcheri* in the lake is probably very low and the population is likely to become extinct if current environmental trends continue. A dramatic reduction in growth rate after 1995 demonstrates the extraordinary growth plasticity of *A. butcheri* in response to environmental influences.

Keywords: salinity, fish kill, growth, Sparidae, thrombolite

Introduction

Lake Clifton is a small, permanently closed, coastal lake on the south-west coast of Western Australia, approximately 100 km south of Perth (lat/long S32.745°, E115.655°). The lake is part of the Peel/Yalgorup system, which was recognised as a 'Wetland of International Importance' under the Ramsar Convention in 1990. The presence of a unique thrombolite (microbialite) community in Lake Clifton was a key factor contributing to this listing. In December 2009, the thrombolites in Lake Clifton were listed as a 'critically endangered ecological community' under the Australian Commonwealth Environment Protection and Biodiversity Conservation (EPBC) Act 1999. Rising salinity in the lake, due to the inflow of increasingly saline groundwater, was identified as the greatest threat to the thrombolite community (Threatened Species Scientific Committee 2010a).

Lake Clifton was hyposaline (salinity range 8–32 gL^{-1}) in the 1970s and 1980s but has become progressively more saline since 1992 and is now frequently hypersaline (Knott *et al.* 2003; Luu *et al.* 2004; Smith *et al.* 2010). Since 2002, annual salinity has typically ranged from a minimum of 20–30 gL^{-1} in winter to a maximum of 70–80 gL^{-1} in autumn (John *et al.* 2009; Smith *et al.* 2010). Lake Clifton receives low surface flow and so the salinity of the lake is mainly a function of groundwater inflow and evaporation (Commander 1988; Davies & Lane 1996). Thrombolites in Lake Clifton have historically formed as a result of the growth of cyanobacteria *Scytonema* sp., which are dependant on a constant discharge of fresh to brackish groundwater directly into their habitat (Moore 1987). Hence, a shift from permanently hyposaline to permanently hypersaline conditions threatens the survival of the key microbial species responsible for thrombolite formation.

In addition to increasing salinity, a range of other threats to the thrombolite community in Lake Clifton have been identified, including physical damage to the thrombolites during feeding by *Acanthopagrus butcheri* (Munro 1949) (Threatened Species Scientific Committee 2010a). Predation by *A. butcheri* has also been suggested as a factor contributing to a decline in the diversity of macroinvertebrate fauna within the lake (Threatened Species Scientific Committee 2010a). The "control and eradication of black bream", which were stocked into the lake, is one of several Priority Actions proposed to aid the conservation of the thrombolite community (Threatened Species Scientific Committee 2010b). This action was proposed in the absence of any survey to assess the current status of the *A. butcheri* population.

Acanthopagrus butcheri is the largest fish species reported from Lake Clifton. This euryhaline species occurs in estuaries and coastal lakes across southern Australia and is highly targeted by recreational fishers across this range (Kailola *et al.* 1993). Anecdotal reports indicate that this species was first introduced to the lake by commercial fishers in 1947 and possibly re-stocked on several subsequent occasions (Dortch 2008; Dortch unpubl. data). Anecdotal reports and genetic evidence indicate the most likely sources of introduced fish are the adjacent estuaries of Peel-Harvey and Leschenault Inlet (Chaplin *et al.* 1998; Dortch 2008).

The population of *A. butcheri* in Lake Clifton was 'rediscovered' in 1996 by recreational anglers who were fishing from a boardwalk recently constructed as a viewing platform for thrombolites. After a 2-week period of intense recreational fishing, the Department of Fisheries implemented a permanent ban on fishing in the lake. The ban was intended to protect the fish (initially thought to be an endemic population) and to prevent accidental damage to the thrombolites.

Prior to this study, information about the status of the *A. butcheri* population in Lake Clifton was derived from a sample of 100 individuals collected in November 2006 (Sarre & Potter 2000). In February 2007 a fish kill resulting in the deaths of hundreds of individual *A. butcheri* created an unexpected opportunity to collect additional samples and reassess this population.

Methods

The fish kill was first reported by members of the public on 13 February 2007. Dead fish were observed floating in shallow water around the thrombolites along the north eastern shore. Dead fish had apparently accumulated in this region as a result of a prevailing south-westerly wind. The total number of dead fish in this area were estimated to be 600–800 (A. Kidd (DEC), pers. comm.).

On 15 February 2007 a random sample of 163 partly decomposed fish was collected from a 100 m length of shoreline adjacent to the thrombolite viewing platform along the north eastern shore. The total length (TL) of each fish was measured to the nearest millimetre. Other biological data such as weight or sex was unobtainable from each fish due to the advanced state of decomposition.

Sagittal otoliths were extracted from 100 fish. A transverse section of 300 μm thickness was taken through the core of one otolith from each fish. Sections were viewed with reflected light against a black background. Age was determined by enumeration of opaque and translucent zones, which are deposited annually in *A. butcheri* otoliths (Morison *et al.* 1998). Opaque zones in *A. butcheri* otoliths are typically deposited during spring (Sarre & Potter 2000). The first complete annual 'increment' was defined as an opaque core followed by a translucent zone plus an opaque zone. Subsequent increments were defined as a translucent zone plus an opaque zone. Each otolith was assigned one of the following margin categories: 1=translucent margin, marginal increment <50% complete; 2=translucent margin, marginal increment >50% complete; 3=opaque margin. All otoliths were read once by an experienced reader and once by a second experienced reader. There was 100% agreement between these readings.

In south-western Australian estuaries, *A. butcheri* typically spawn between October and December (Sarre & Potter 1999). Therefore, an average birth date of 1 November was assigned to all fish collected from Lake Clifton in 2007.

Results and Discussion

High salinity and low oxygen have been suggested as factors contributing to the sudden mortality of black bream in Lake Clifton in February 2007 (John *et al.* 2009). Oxygen and salinity are infrequently monitored in Lake Clifton and levels immediately prior to the fish kill were not available. However, salinity measured shortly after the kill, in February 2007, was 79 gL^{-1} (John *et al.* 2009). This is approaching the upper salinity tolerance for *A. butcheri* and likely to result in osmotic stress (Partridge & Jenkins, 2002; Hoeksema *et al.* 2006). However, high salinity does not appear to have been the primary cause of death in 2007. A period of increasing salinity, eventually reaching a lethal level, would be expected to result in an extended period of stress and probably also a protracted period of mortality. The fins and skin of dead fish were intact and did not show signs of external lesions, disease or injuries that are often seen on fish that have been subjected to a long period of extreme osmotic stress (Hoeksema *et al.* 2006). The external condition of the fish suggested that death occurred relatively rapidly. Also, all fish were at a similar stage of decomposition, suggesting that they had died at approximately the same time.

The fish kill coincided with the sudden, widespread dislodgement of large benthic microbial mats in the lake (John *et al.* 2009). Dead fish and pieces of microbial mats, up to 50 cm in diameter, were observed floating together among the thrombolites. The decomposition of these mats may have created hypoxic zones and led to the sudden asphyxiation of fish. Hence, asphyxia was likely to be the primary cause of death in Lake Clifton in February 2007.

The total lengths of dead *A. butcheri* collected from Lake Clifton in February 2007 ranged from 235 to 328 mm, with an average length of 271 + 14 (+ s.d.) mm. All fish were estimated to be 11 years old and therefore spawned in late 1995.

The mean length-at-age of fish collected in 2007 was substantially lower than that predicted by von Bertalanffy growth parameters derived from fish collected from Lake Clifton in 1996 (429 mm TL at 11 years of age) (Sarre & Potter 2000) (Fig. 1). In 1996, the *A. butcheri* population in Lake Clifton exhibited a relatively fast growth rate, which was significantly higher than growth measured in three other south-western Australian estuaries (Moore River, Walpole/Nornalup Inlet, Wellstead Estuary) and slightly higher than growth

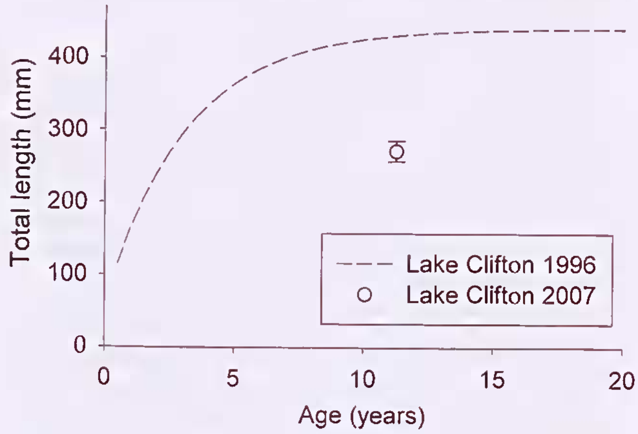

Figure 1. Length-at-age of *Acanthopagrus butcheri* collected from Lake Clifton in 1996 (represented by von Bertalanffy growth curve fitted by Sarre (1999)) and length-at-age (mean + s.d.) of fish collected from Lake Clifton in 2007.

measured in the Swan Estuary (approximately 90 km to the north of Lake Clifton) (Sarre & Potter 2000). The magnitude of the decline in growth in Lake Clifton between 1996 and 2007 indicated that all of the fish collected in 2007 had experienced slow growth over numerous years. Overall, these observations suggest that environmental conditions in Lake Clifton were relatively favourable to the growth of *A. butcheri* prior to 1996 but were unfavourable after 1996.

Previous observations of differences in growth rates among estuaries have provided evidence of the plasticity of growth by *A. butcheri* (Sarre & Potter 2000). These differences are environmentally driven and do not reflect genetic differences between populations (Partridge *et al.* 2004). The decline in growth of *A. butcheri* in Lake Clifton between 1996 and 2007 further demonstrates the extraordinary growth plasticity of this species in response to environmental factors.

Acanthopagrus butcheri can tolerate a wide range of salinities, from 0 to at least 60 gL^{-1}. Juveniles and adults typically display signs of osmotic stress, including reduced growth, external lesions and mortality at salinities above 60 gL^{-1}, although adult fish have been observed in the wild at salinities of up to 114 gL^{-1} (Partridge & Jenkins 2002; Hoeksema *et al.* 2006). The extremely slow growth of *A. butcheri* collected from Lake Clifton in 2007 suggests that these individuals may have experienced prolonged periods of osmotic stress and spent a substantial part of their life at salinities above 60 gL^{-1}.

Other factors could also have potentially affected the growth rate of *A. butcheri* in Lake Clifton. In particular, increased salinity may have altered the composition of the invertebrate community in the lake, forcing a change in the diet of *A. butcheri*. However, the stomach contents of fish sampled in 1996 were dominated (40% by volume) by *Capitella capitata* (Polychaeta), which was abundant in Lake Clifton sediments in the late 1990s (Sarre *et al.* 2000; Konishi *et al.* 2001). *Capitella capitata* is extremely euryhaline (Geddes & Butler 1984) and is likely to have remained abundant despite recent hypersalinity. Therefore, the dominant prey item consumed by *A. butcheri* was probably relatively constant from 1996 to 2007 and a dietary shift is unlikely to have caused the decline in growth.

In addition to effects on growth, recent environmental conditions in Lake Clifton appear to have also negatively impacted on the reproductive output of *A. butcheri*. A sample of 100 *A. butcheri* collected from the lake in 1996 included ten age classes ranging from 1 to 19 years (Sarre 1999). This suggested that spawning had occurred in at least 10 of the years from 1977 to 1995. In 2007, the absence of all year classes except 1995 suggests limited or zero recruitment in 1996 and all subsequent years.

It is unlikely that many of the fish captured in 1996 were introduced (*i.e.* spawned elsewhere and translocated to Lake Clifton). In 1996, anglers removed many hundreds of large bream from the lake. Also, anecdotal reports from fishers indicate that some fishing had been occurring for several years prior to 1996. Even after this population depletion, numerous large fish were still available to be captured by Sarre (1999). These high catch rates, occurring after the effects of fishing and natural mortality, imply a high initial abundance of each age class. This would have required substantial quantities of fish to be stocked into the lake each year. A more likely mechanism is natural recruitment. Hence, the majority of the fish collected in 1996 and in 2007 were probably spawned in Lake Clifton and were the descendants of a small number of introduced fish.

Reproduction by *A. butcheri* (as measured by sperm motility, egg fertilization, egg survival and larval development) can occur at salinities of 10–35 gL^{-1} but, within this range, is most successful at salinities of 20–35 gL^{-1} (Haddy & Pankhurst 2000). This optimal range reflects the salinities at which *A. butcheri* typically spawns in the wild (Nicholson *et al.* 2008). The potential of *A. butcheri* to reproduce successfully at salinities above seawater has not been examined. However, in the congeneric *Acanthopagrus berda*, sperm motility occurs over a wide salinity range (5–60 gL^{-1}) but peaks sharply at approximately 25–35 gL^{-1} (Molony & Sheaves 2001). In another euryhaline sparid, *Sparus sarba*, hatching of viable larvae is limited to salinities of 9–54 gL^{-1} but highest rates occur between 20–36 gL^{-1} (Mihelakakis & Kitajima 1994). The optimal salinity ranges for these species correspond to the salinities at which they typically spawn in the wild. Therefore, it is likely that reproductive success of *A. butcheri* declines rapidly as salinity increases beyond 35 gL^{-1} and is limited to salinities well below 60 gL^{-1}.

Despite substantial penalties for unlawful translocations of fish, introductions of non-endemic *A. butcheri* into inland lakes is a widespread problem in south-western Australia, with various potential ecological, social and economic impacts (*e.g.* Smith *et al.* 2009). Most recently, a population of *A. butcheri* was discovered in Lake Thetis, another inland lake containing a significant benthic microbial community (Grey *et al.* 1990; N. Casson [DEC] pers. comm.). *Acanthopagrus butcheri* in Lake Thetis were discovered during a fish kill in February 2010. The salinity of Lake Thetis is typically hypersaline and was approximately 57 gL^{-1} during the fish kill (K. Smith unpubl. data). As with Lake Clifton, this discovery generated concerns about the potential impacts to microbialites and whether management action should be taken. Improved knowledge of the upper salinity limits for reproduction, growth and survival by *A. butcheri* would assist in determining the need for management action in such cases.

In summary, the environmental conditions in Lake Clifton since 1995 appear to have been highly unfavourable for both growth and reproduction of *A. butcheri*. High salinity is likely to be the primary factor contributing to slow growth and recruitment failure. Given that salinity is predicted to remain high, and possibly increase, it appears unlikely that any surviving *A. butcheri* in the lake will successfully breed again.

The proposed conservation strategy for Lake Clifton aims to address a range of identified threats to thrombolites, including the eradication of the introduced *A. butcheri* population (Threatened Species Scientific Committee 2010b). However, management action in response to this particular threat may no longer be required. The abundance of *A. butcheri* in the lake is probably very low and the population is likely to become extinct if current environmental trends continue.

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